Higgs searches at CDF: Standard Model and beyond

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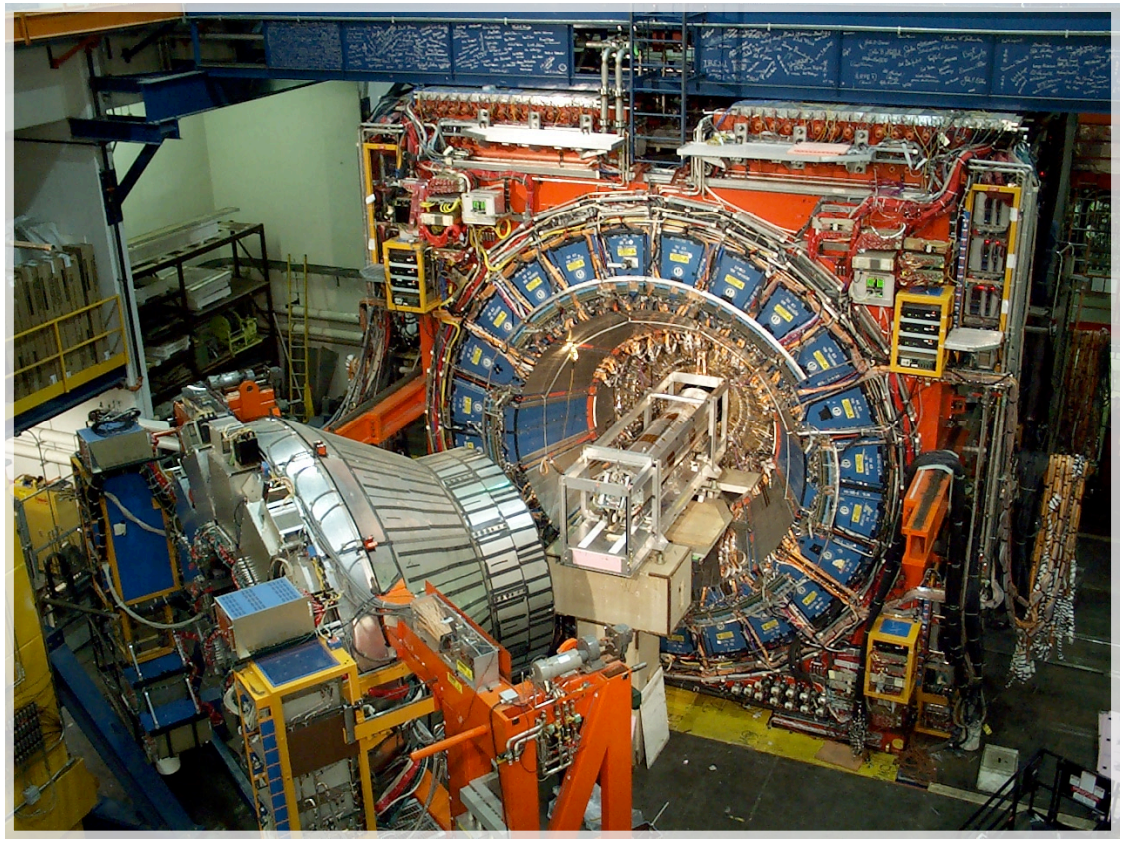
for the CDF collaboration

Outline

- The Tevatron and CDF
- SM Higgs results
- BSM Higgs results
- Conclusions



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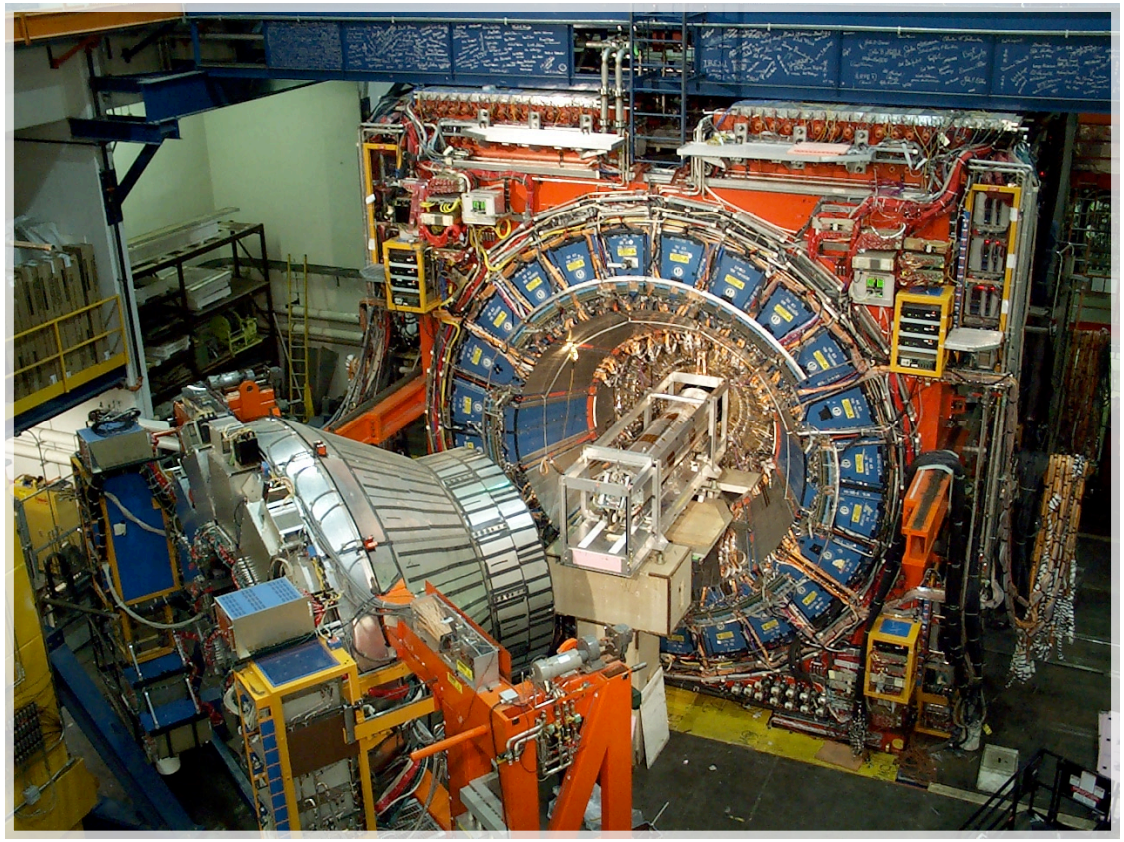
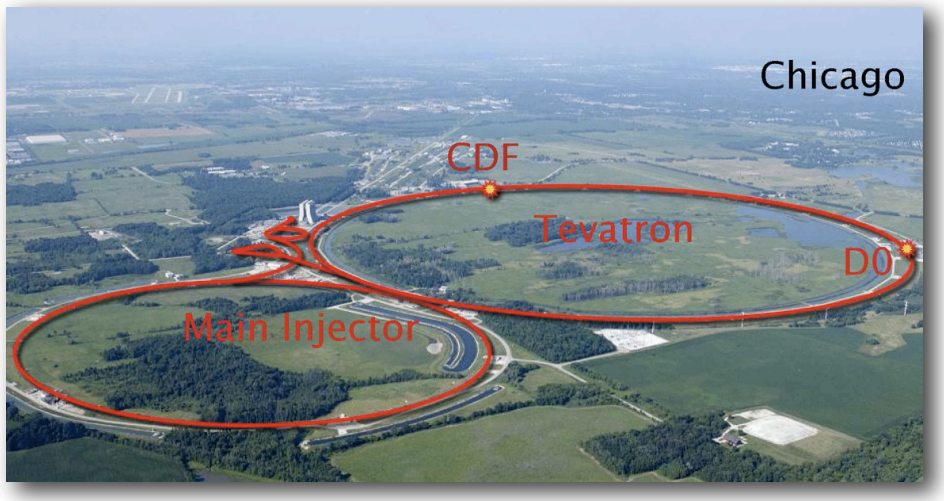
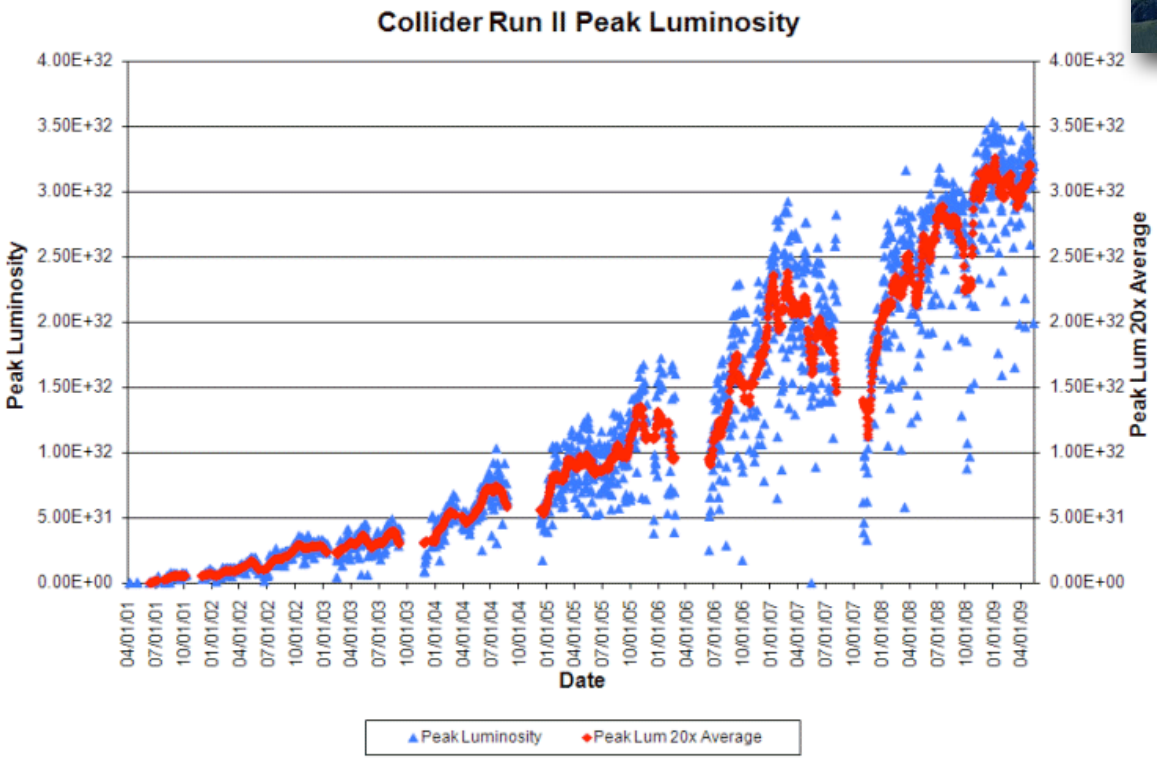


The Tevatron

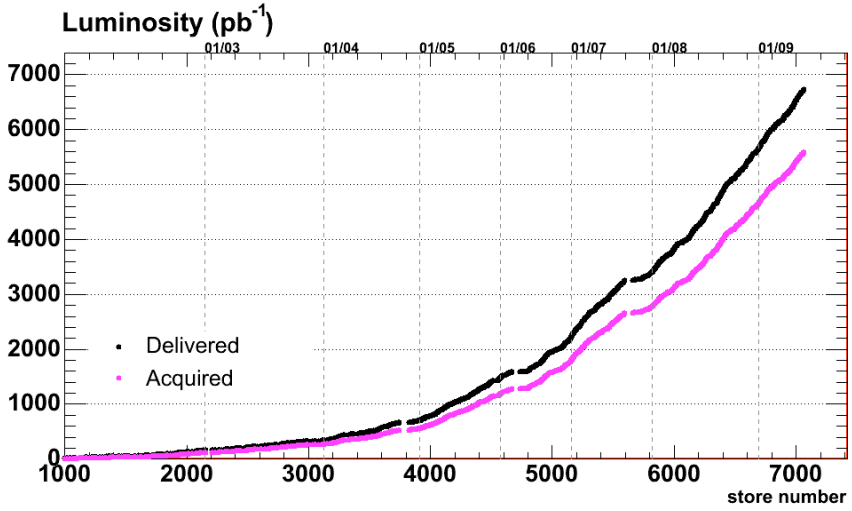
- $p\bar{p}$ collisions at $s^{1/2}$ = **1.96 TeV**
- 36×36 bunches, **396 ns** crossing period.

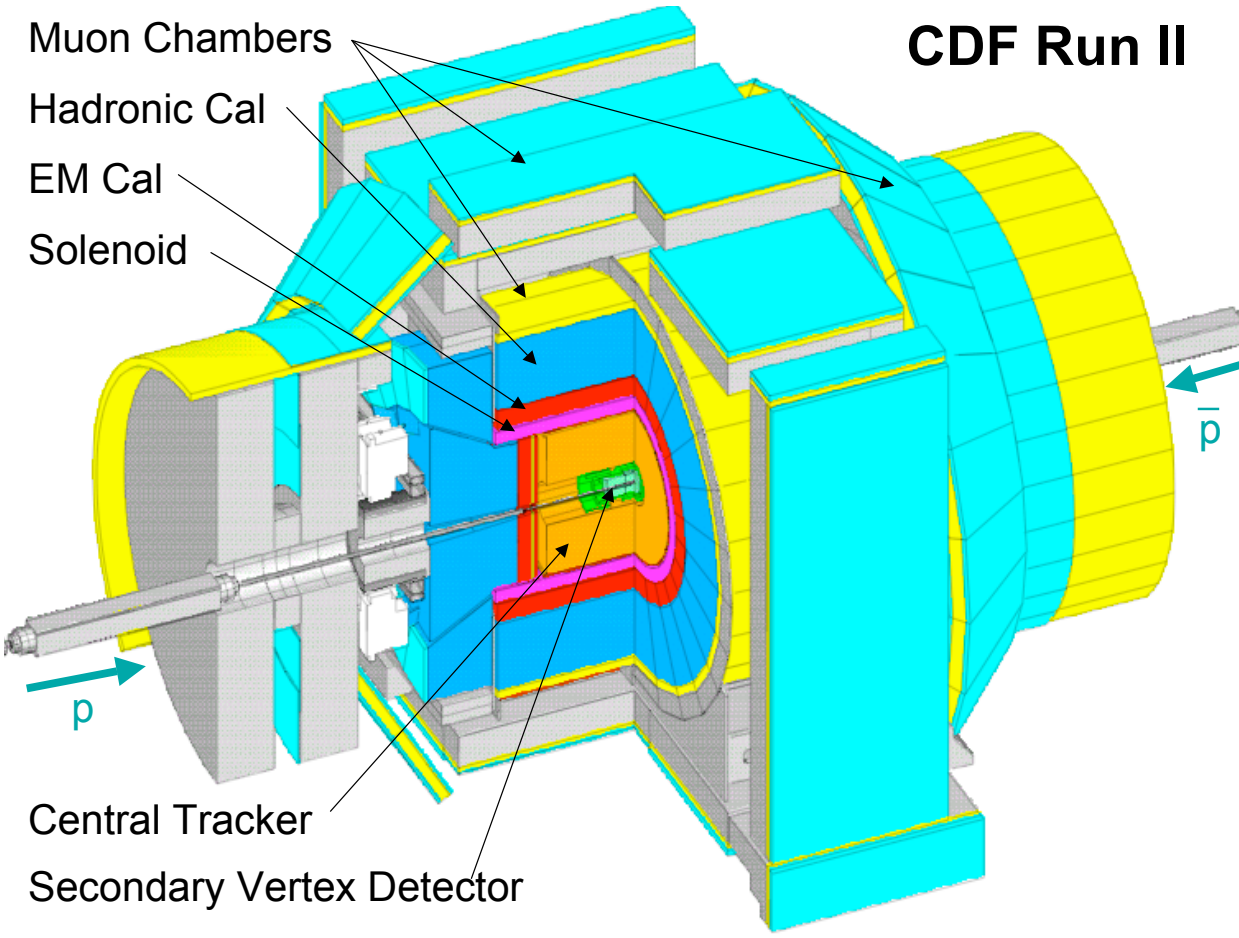




- Initial instantaneous luminosity record: **> 3.5×10^{32} cm^{-2}s^{-1}**.
- Delivered luminosity > **6.5 fb^{-1}** since the beginning of Run II

CDF





- Over **5.5 fb^{-1}** of data on tape
- 85-90% data taking efficiency
- Results shown here use **2 to 4 fb^{-1}**

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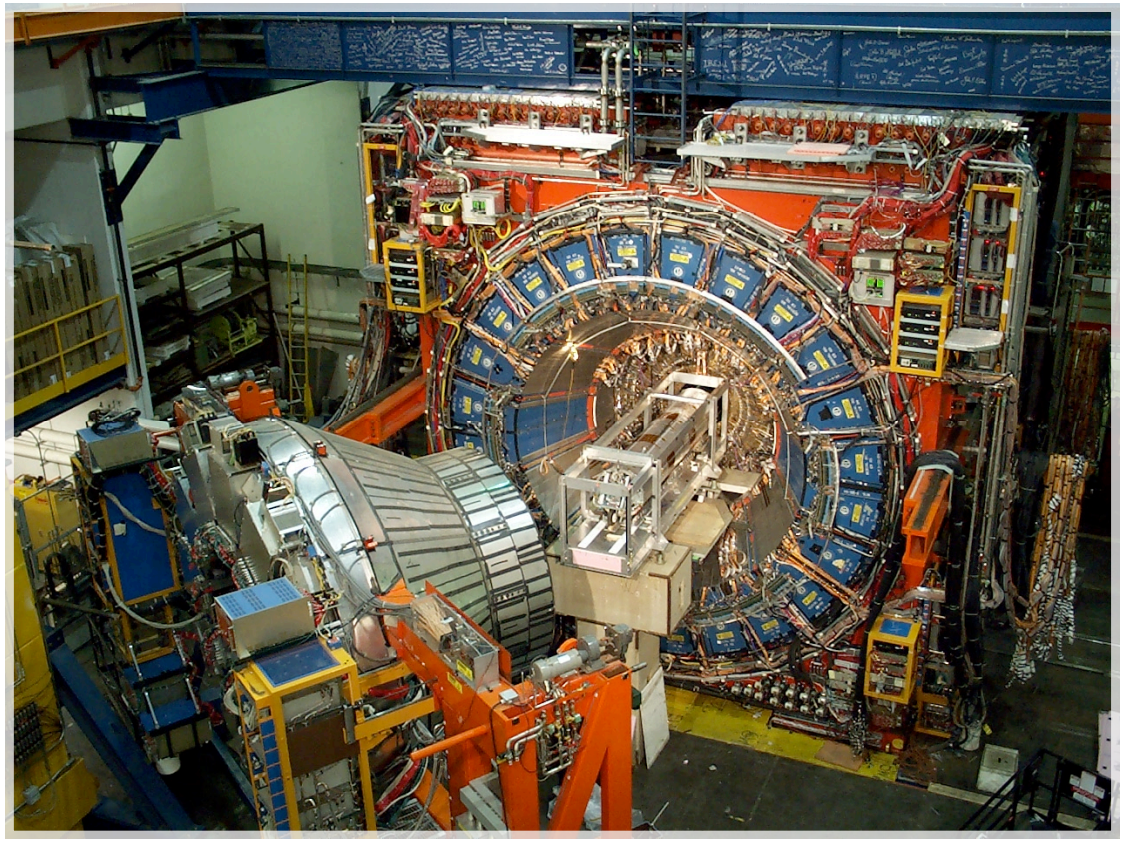
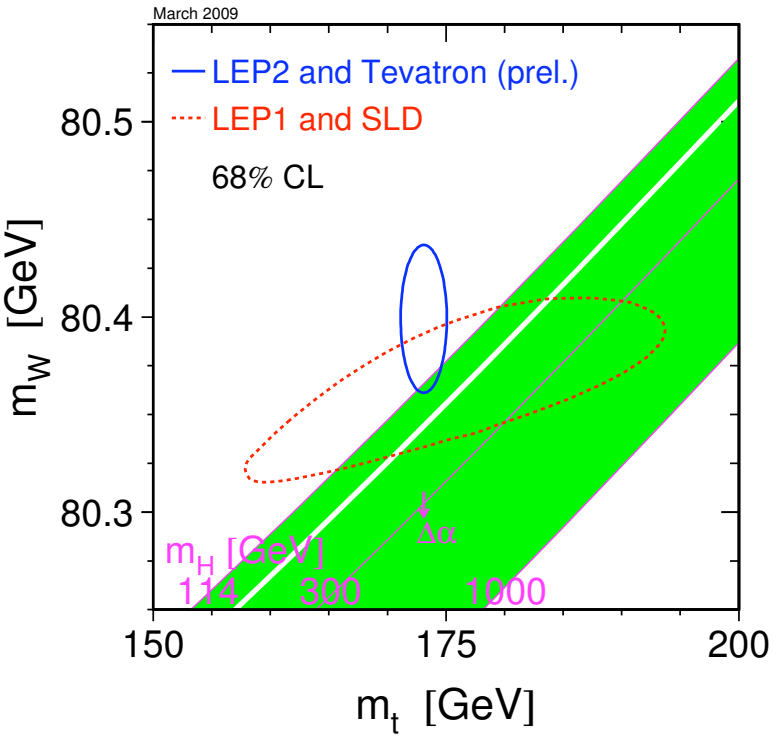
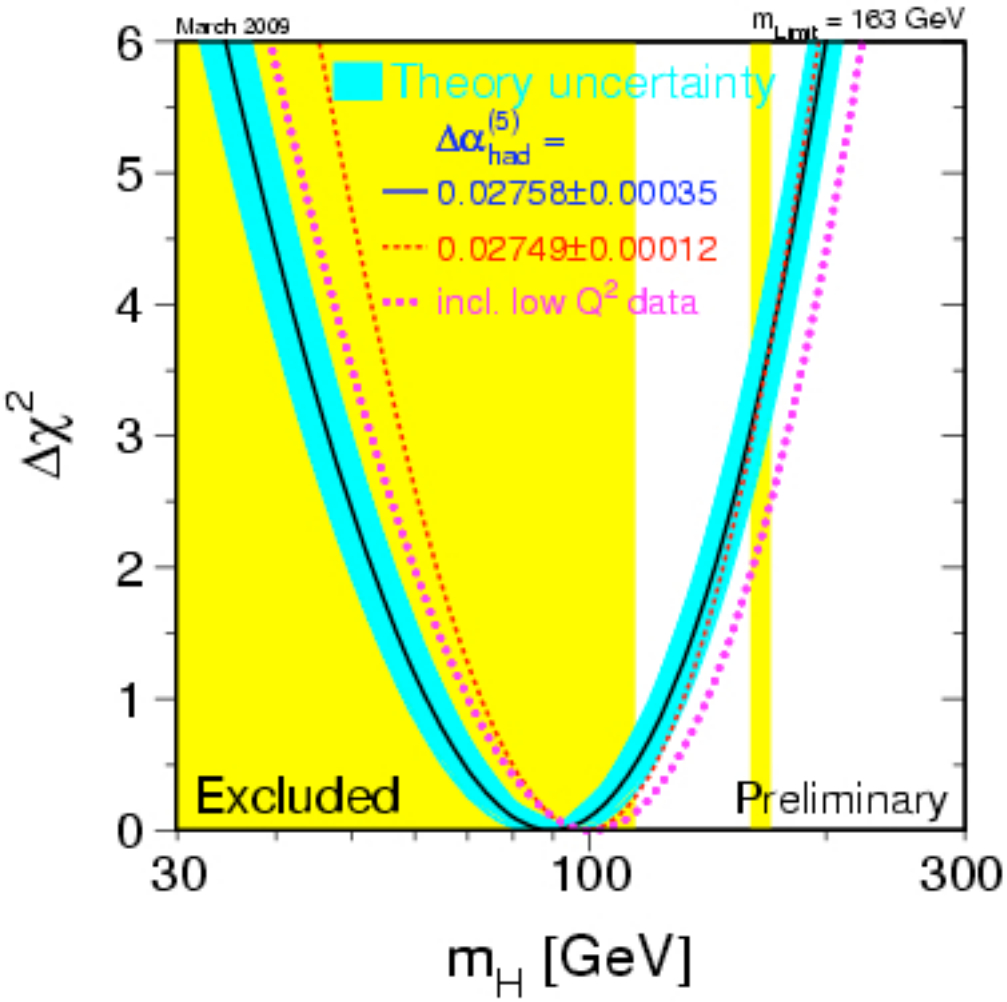


Constraints on the SM Higgs mass

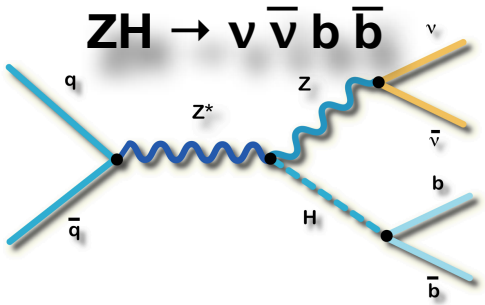
- Global fit with Tevatron's
  m_{top} = **173.1 ± 1.3 GeV** and
  m_W = **80.399 ± 0.023 GeV**
- m_H = **90^{+36}_{-27} GeV**
- m_H < **163 GeV** @ 95 % CL

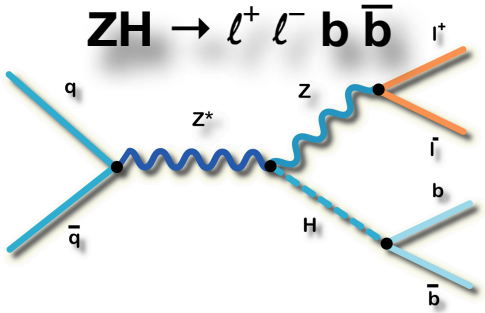


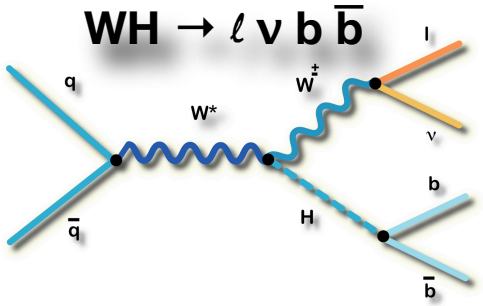


- Direct searches at LEP:
  m_H > **114.4 GeV** @ 95% CL

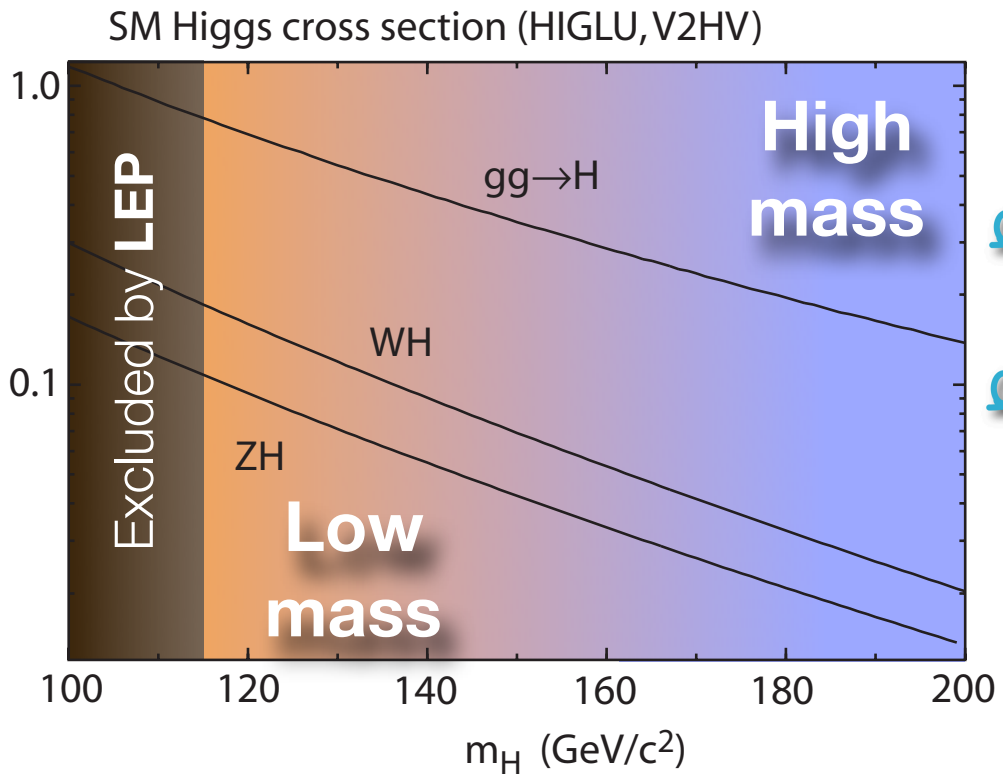
SM Higgs cross section

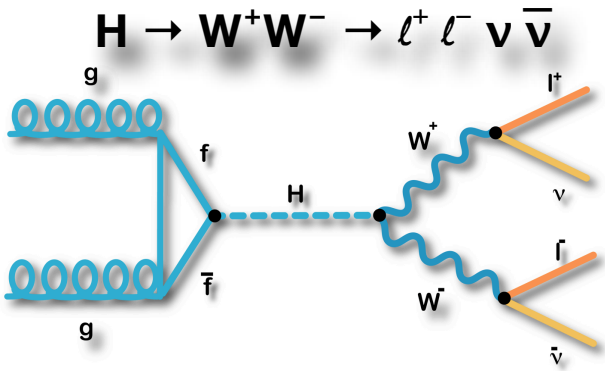




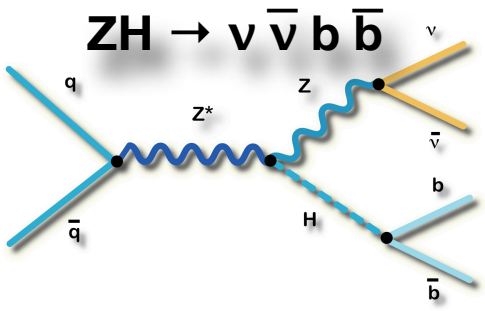


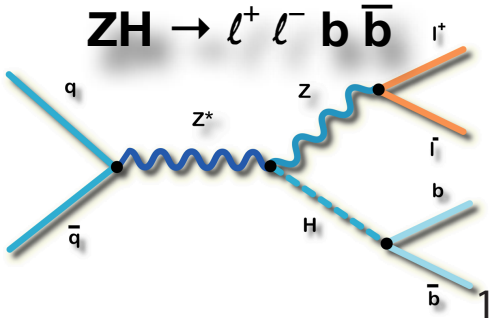
- Cross sections in **pb**

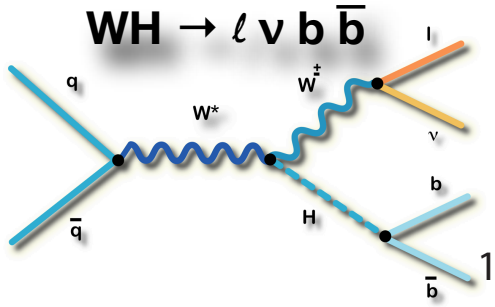


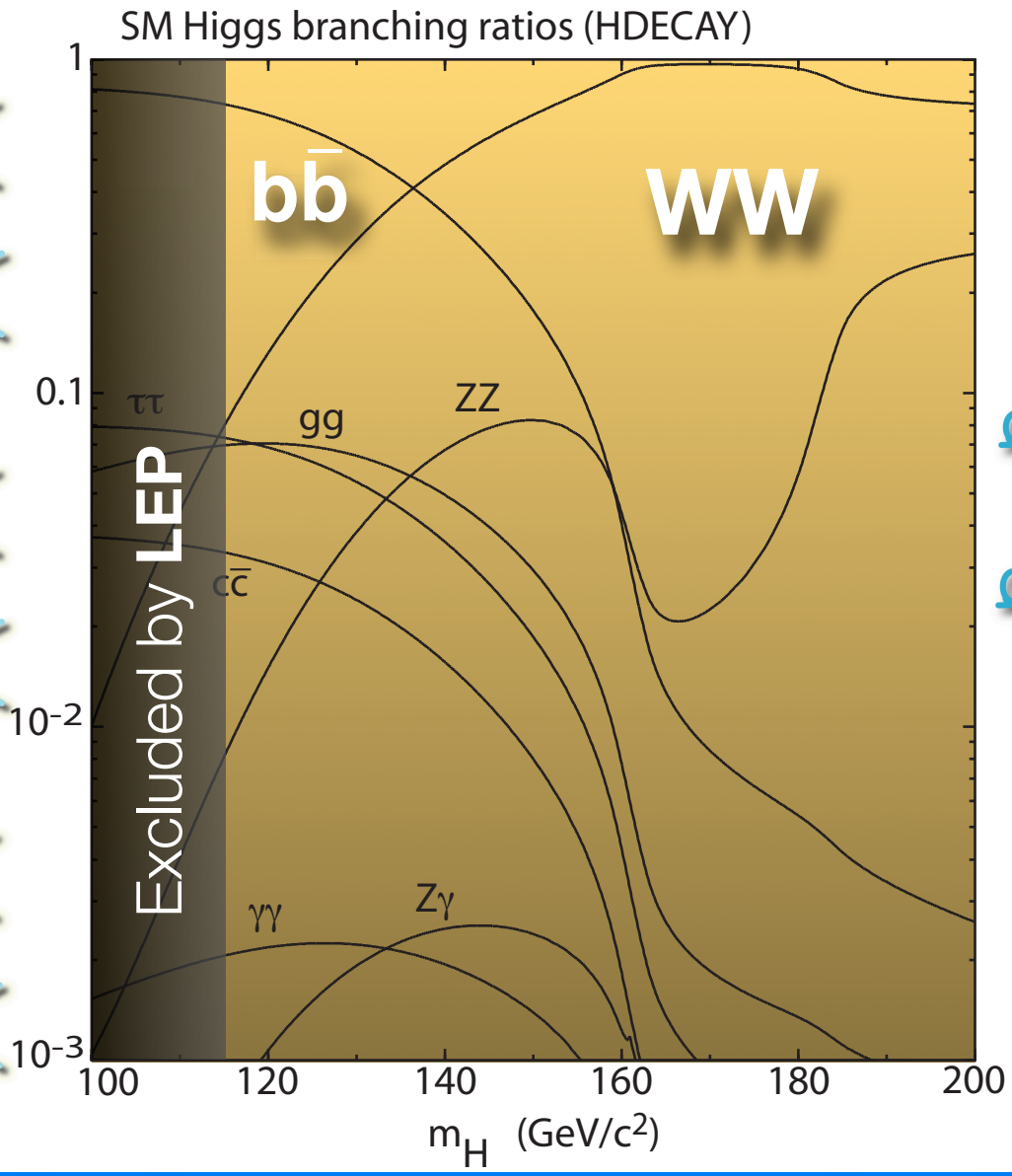


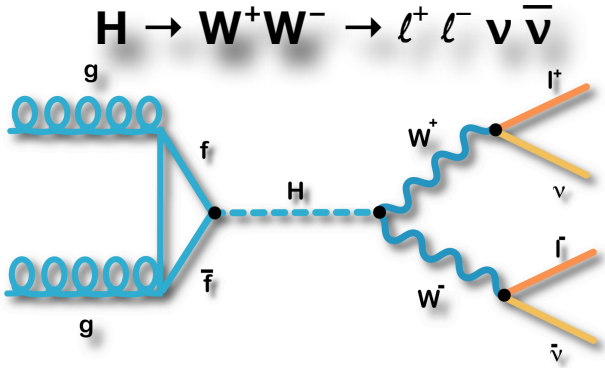
SM Higgs branching ratios



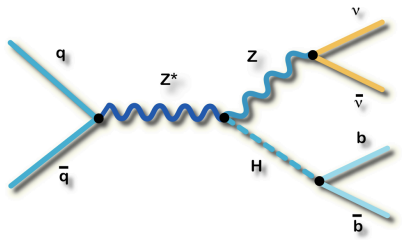






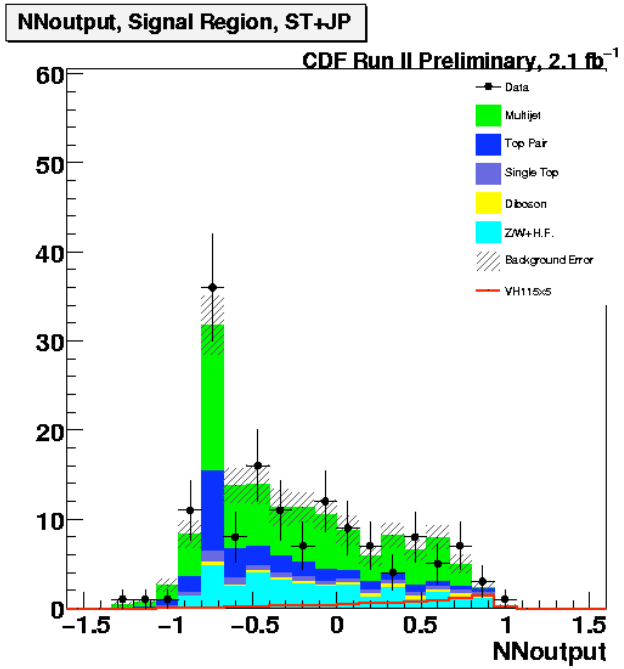


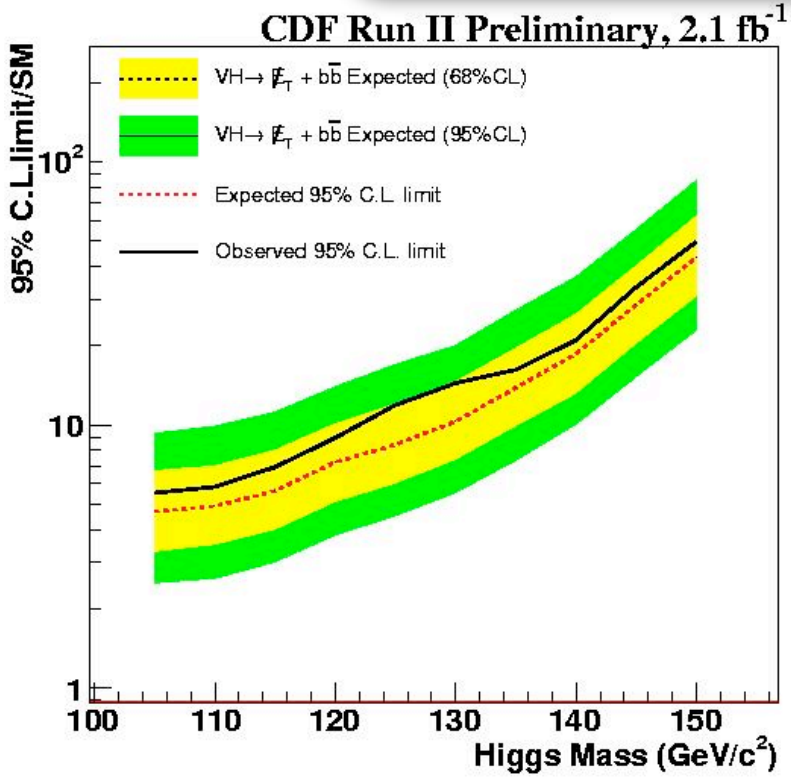
$ZH \rightarrow \nu\bar{\nu}\, b\bar{b}$



luminosity **2.1 fb^{-1}**
exp limit@115GeV/SM **5.6**
obs limit@115GeV/SM **6.9**

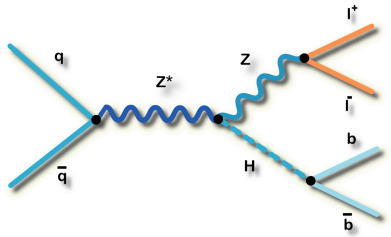
- Large E_T^{miss} and 2 or 3 jets (at least 1 b-tagged)
- Extra signal from **WH** (missing lepton)
- Main **background**: QCD, W+jets and top pairs



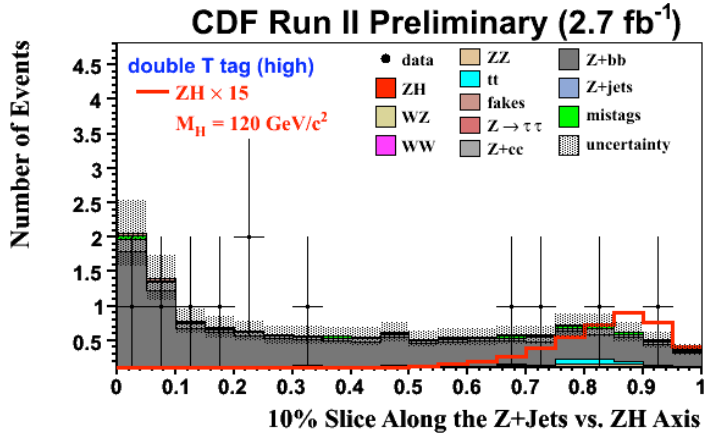


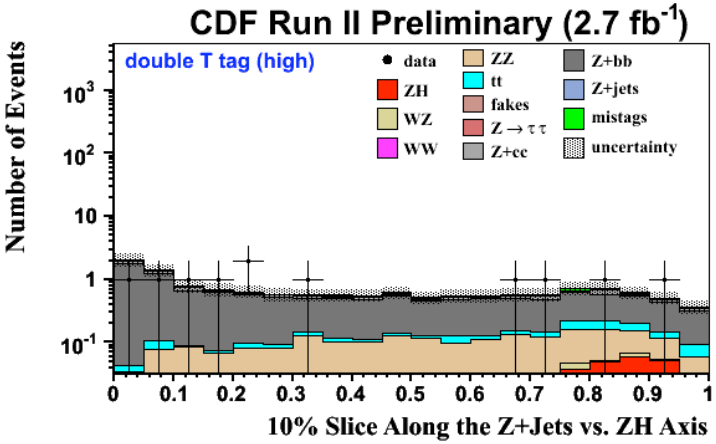
- **Data driven QCD** background estimation:
  - NN with p_T^{miss}.
- Events with a **3rd jet** also included to increase WH acceptance
- Signal/background **NN discriminant**

$ZH \to \ell^+ \ell^- b\bar{b}$

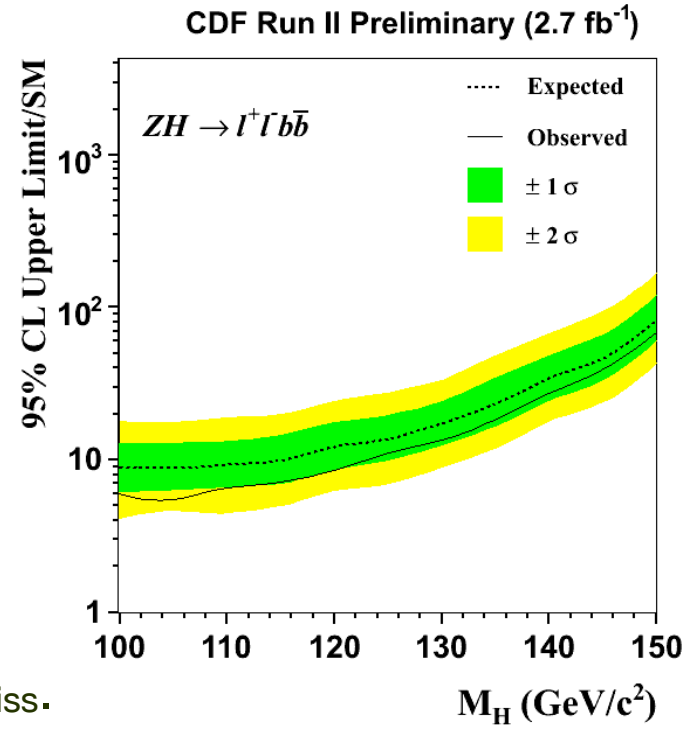


luminosity **2.7 fb^{-1}**
exp limit@115GeV/SM **9.9**
obs limit@115GeV/SM **7.1**





- **Low event rate** but clean signature
  - acceptance is crucial
  - loose lepton/b-tagging
- 2 high p_T leptons, from Z
- 2 high E_T jets, with 1 or 2 b-tags

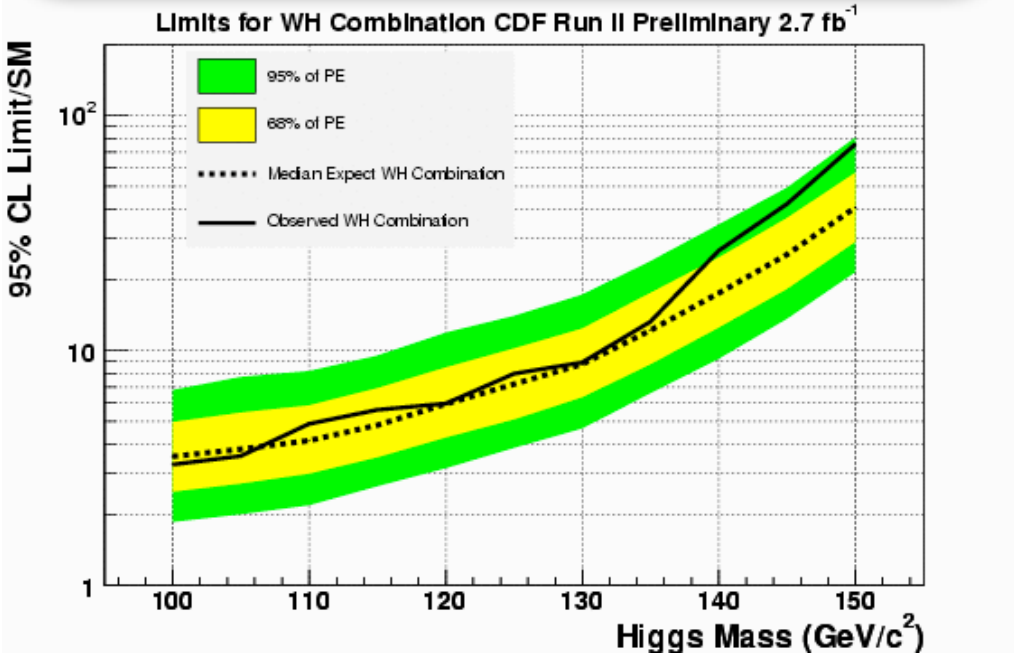


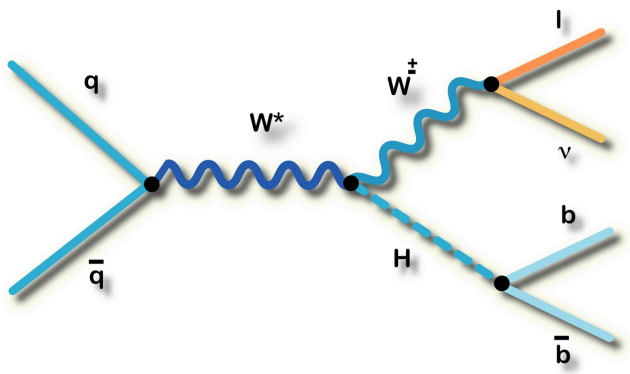
- **Backgrounds**: mainly Z+jets, also top pairs
- **2D Neural Network** trained to separate ZH from backgrounds
- Improve **dijet mass resolution** using measured $\not\!\!E_T^{miss}$.

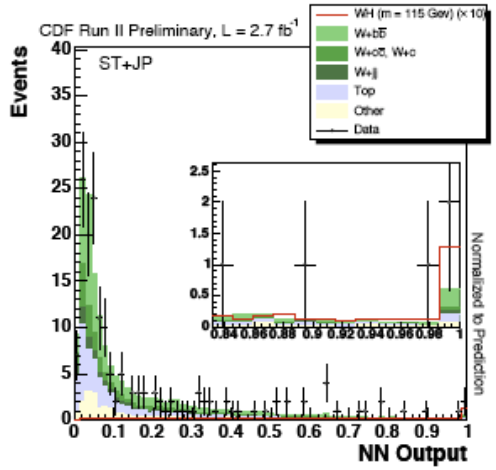
$WH \rightarrow \ell \nu b \bar{b}$

	NN	ME+BDT	Combo
luminosity	2.7 fb^{-1}	2.7 fb^{-1}	2.7 fb^{-1}
exp limit@115GeV/SM	5.8	5.2	4.8
obs limit@115GeV/SM	5.2	6.2	5.6

- **Most sensitive channel at low mass**
- Basic selection
  - high p_T lepton (3 categories)
  - 2 high E_T jets
  - large E_T^{miss}
  - 1 or 2 b-tags
- Two separate analyses combined:
  - **NN discriminant**
  - **BDT discriminant** (with ME probabilities as input)
- Main **backgrounds**: W+jets and top pair production

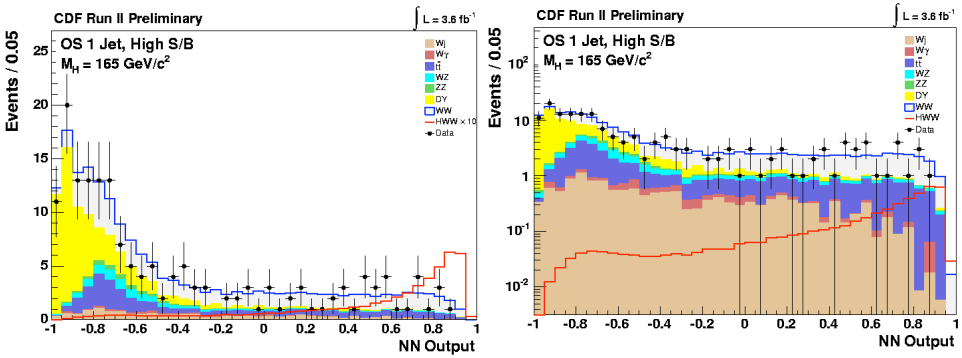


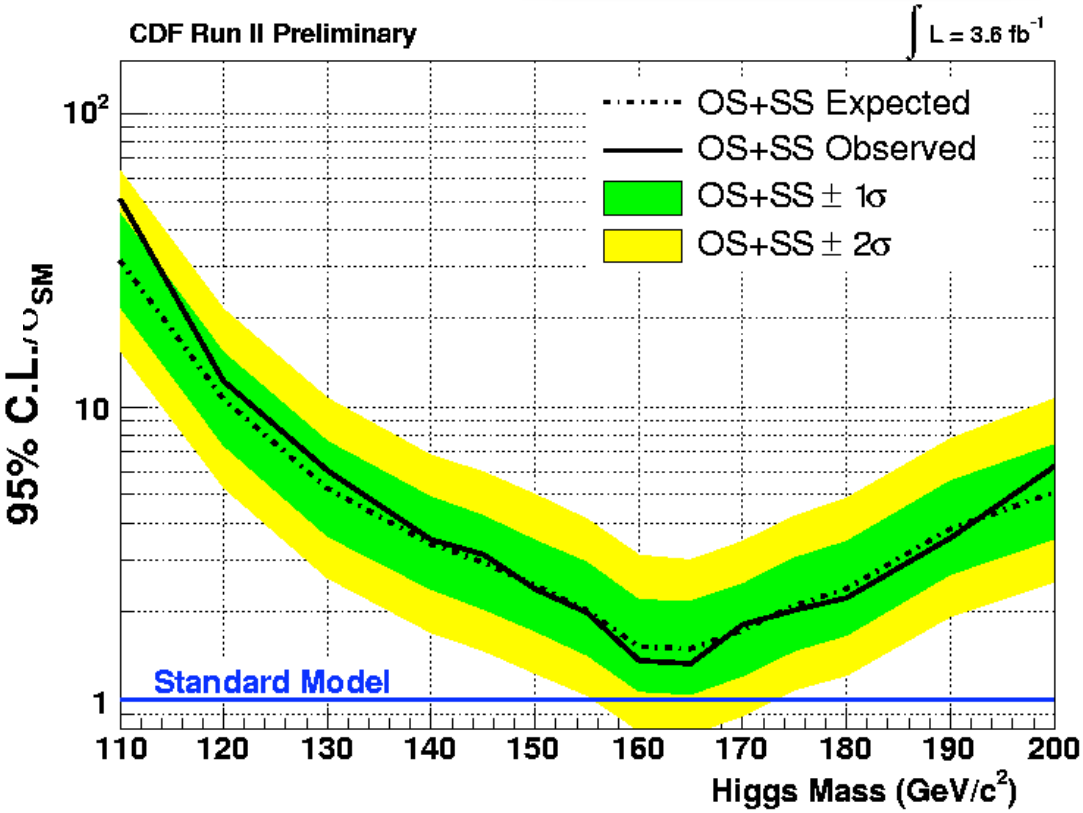




$H \to W^+W^- \to l^+ l^- \nu \bar{\nu}$

luminosity $3.6\ fb^{-1}$
exp limit@160 GeV/SM 1.5
obs limit@160 GeV/SM 1.4



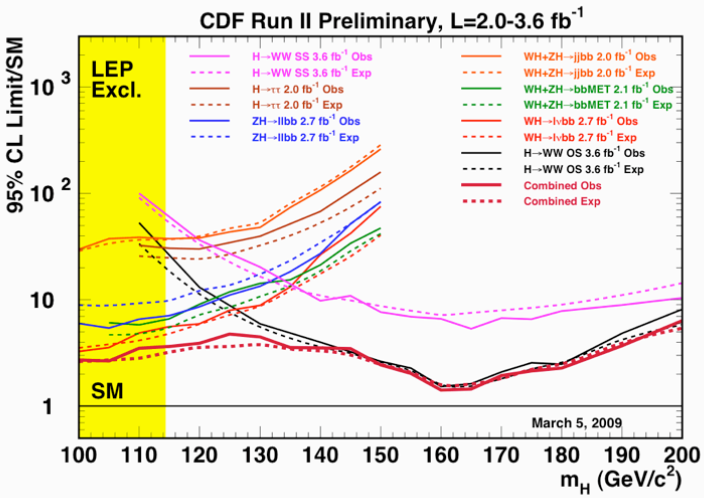


- **Most sensitive channel at high mass**
- Basic selection
  - 2 high p_T lepton
  - large E_T^{miss}
- **Same sign** leptons also included to catch associate production
- Sample separated in **jet multiplicity** 0, 1 and 2 or more jets

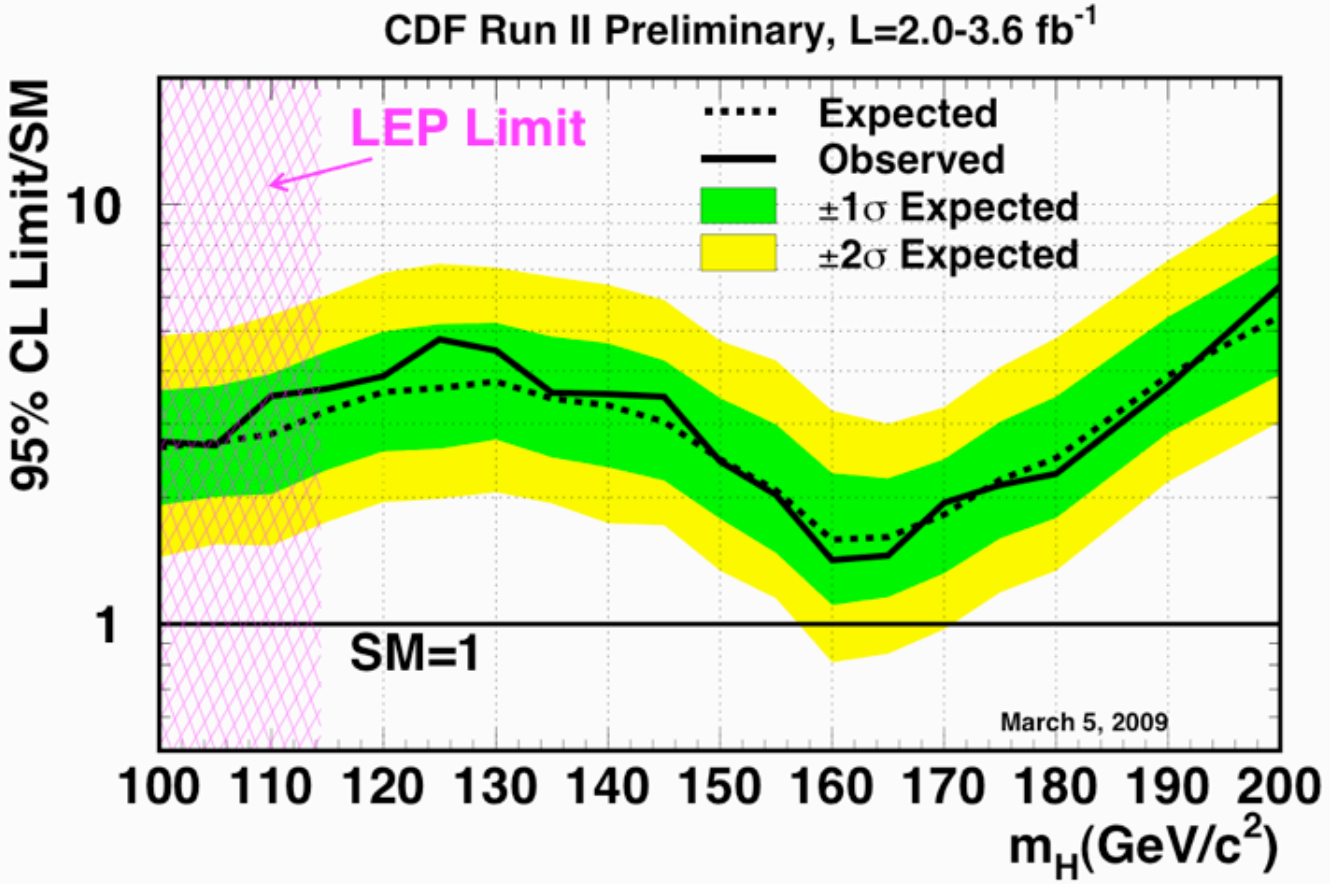
- **NN discriminant**
  - LLR based on ME as input variable

CDF Combination

luminosity 2.0-3.6 fb^{-1}
obs limit@115 GeV/SM 3.6
obs limit@160 GeV/SM 1.4



- Different channels and techniques combined in a **single result**
- **Sensitivity** approaching fast **SM predictions**



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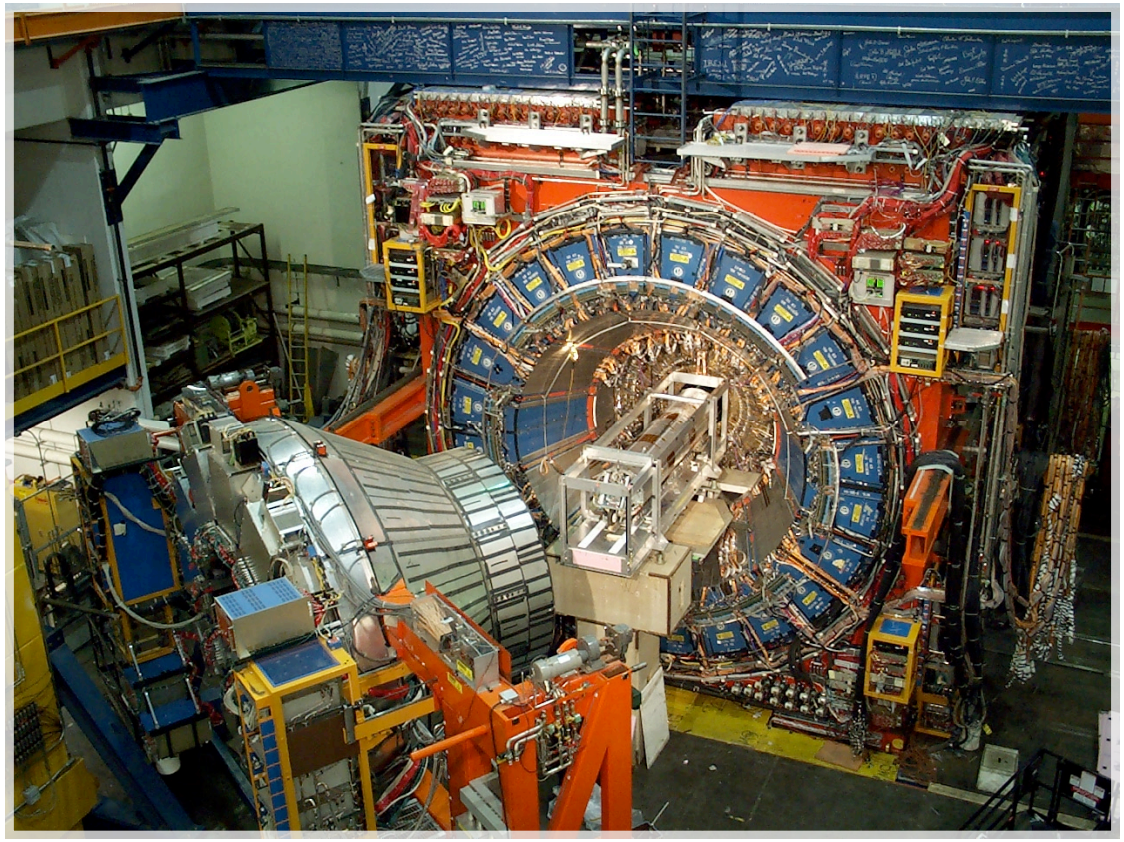
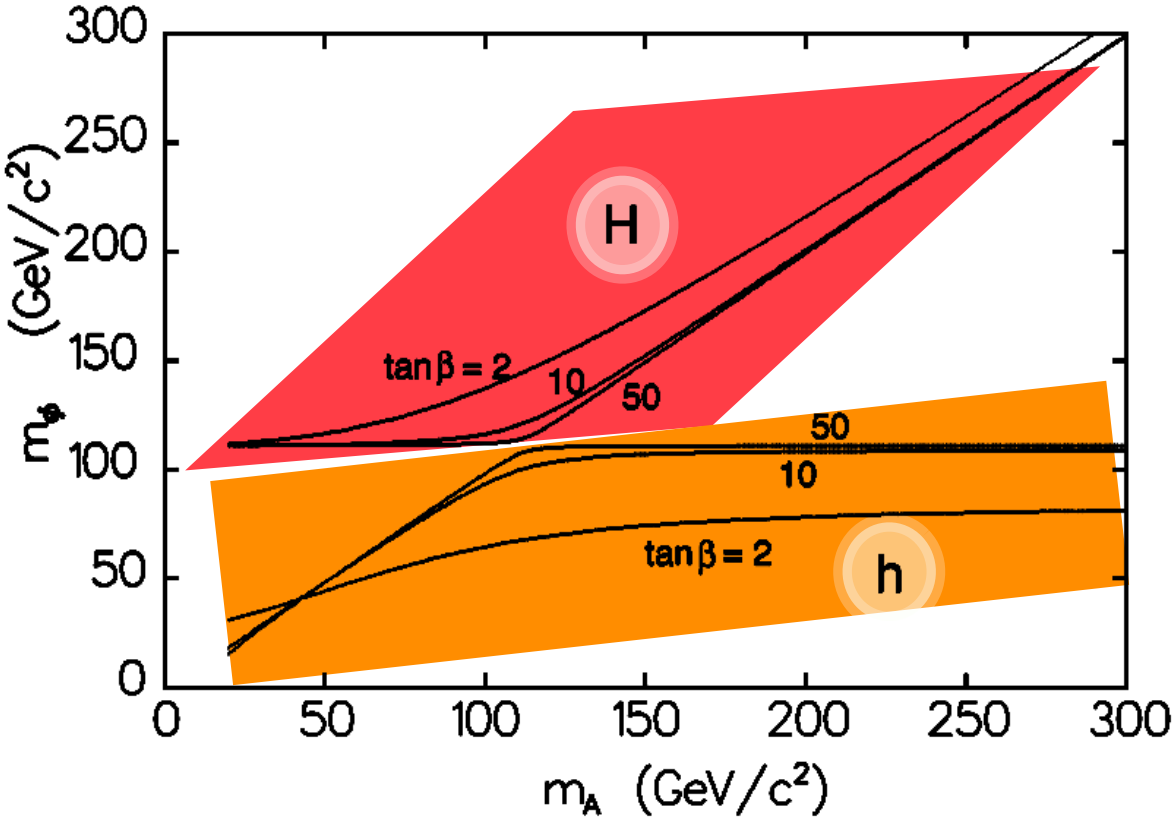


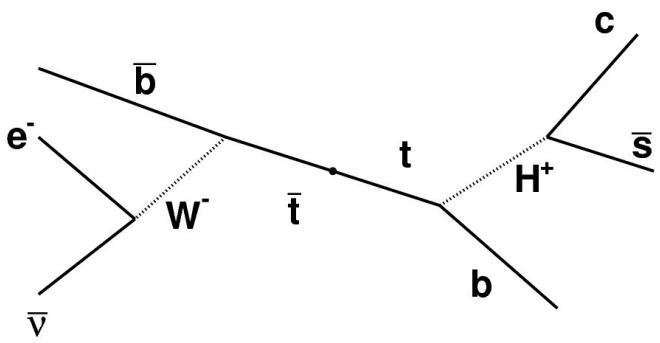
MSSM Higgs sector

- Minimal Supersymmetric extension of the Standard Model
- MSSM is a SUSY model with **2 Higgs doublets**
- 5 Higgs bosons: **h, H, A, H^+ and H^-**
- At tree level, 2 parameters, **m_A and tanβ**, describe the MSSM Higgs sector
- tanβ: **ratio of couplings** to down and up type quarks*
- At large tanβ, 2 neutrals almost **degenerate** in mass, referred as ϕ



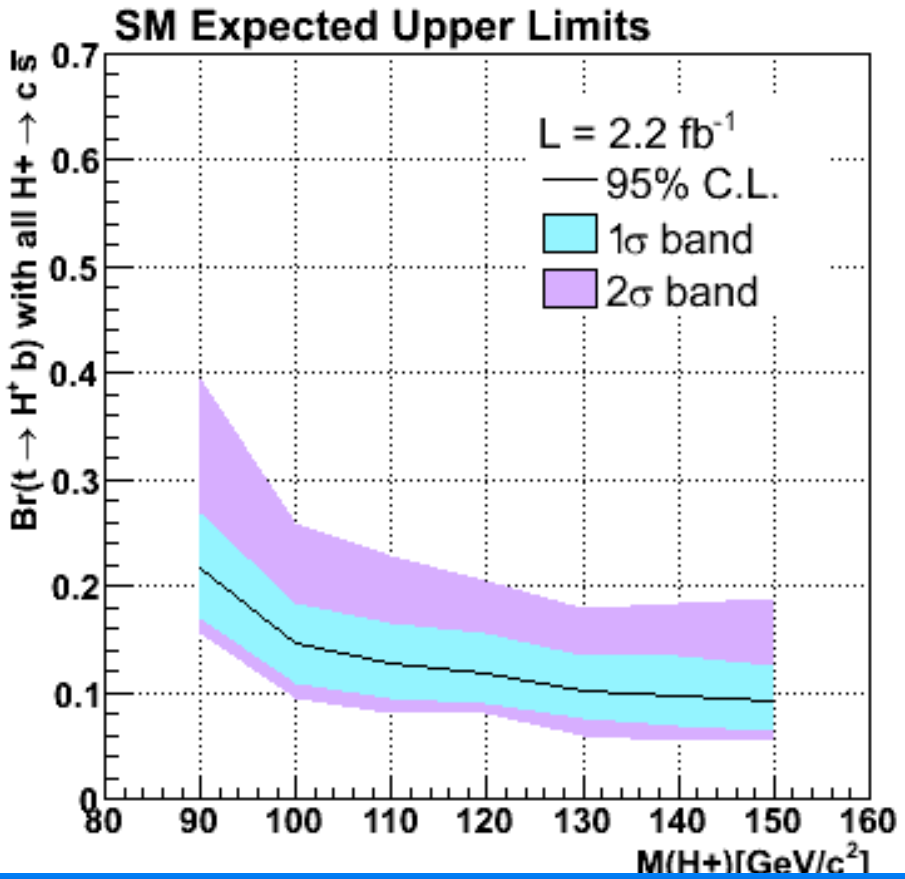
*actually, **tanβ** is the ratio of the VEV of the doublets. The couplings are proportional to the VEV at tree level, before radiative corrections

Charged Higgs

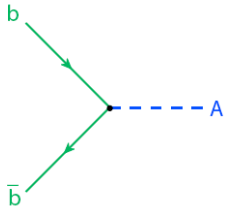


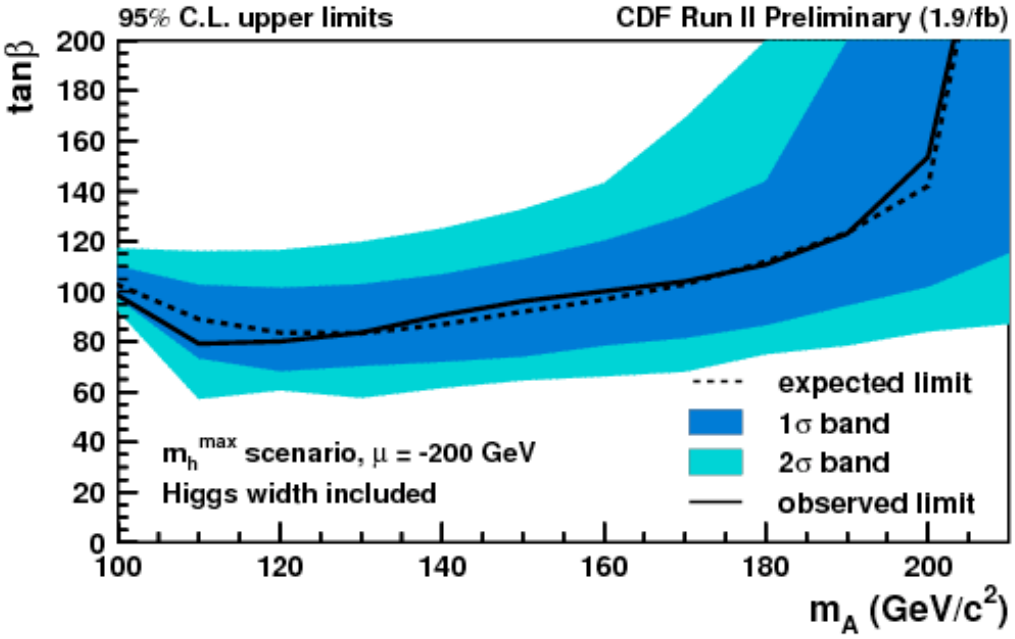
- Analysis performed with **2.2 fb^{-1}**
- Event selection:
  - one high p_T lepton
  - large E^T_{miss}
  - at least four central jets
  - at least 2 b-tagged jets
- Binned likelihood **fit to di-jet mass** to extract signal, limits

- Search in the **top pair sample**
  - a top quark decays to a charged Higgs
  - viable at **low tanβ**, ~1



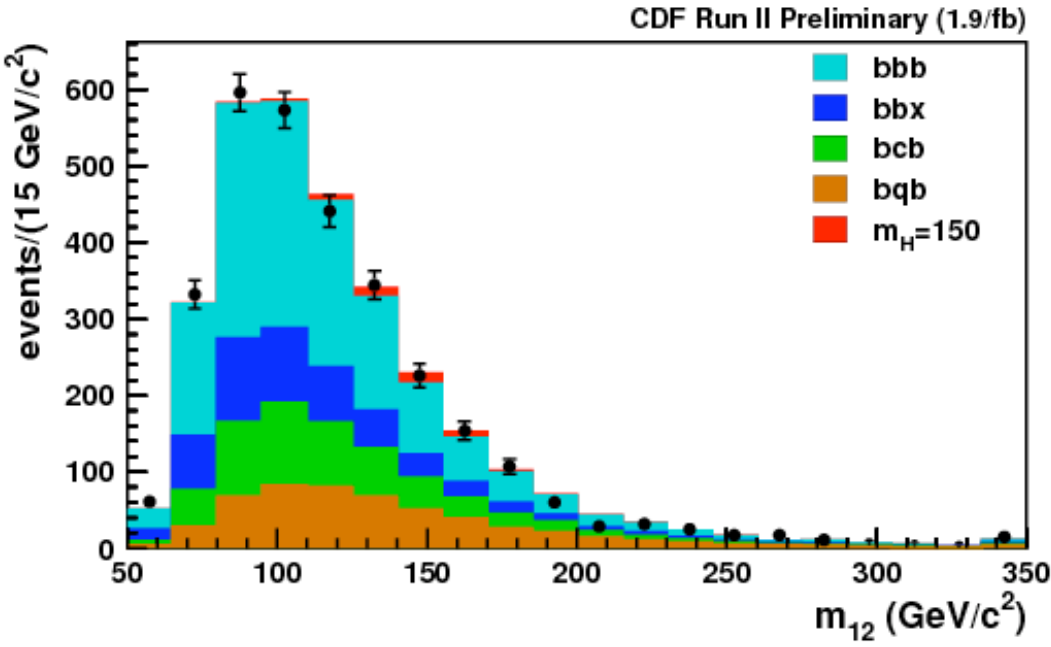
Neutral Higgs: $H \rightarrow b\bar{b} + b + (\bar{b})$



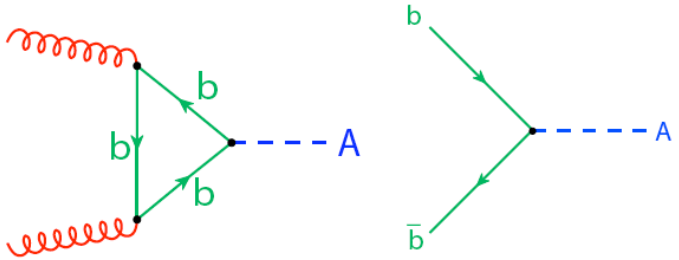


- Binned **maximum likelihood fit** used for limit setting
- Accounting for the Higgs **width** dilutes sensitivity
- **Loop corrections** reduce sensitivity in tanβ

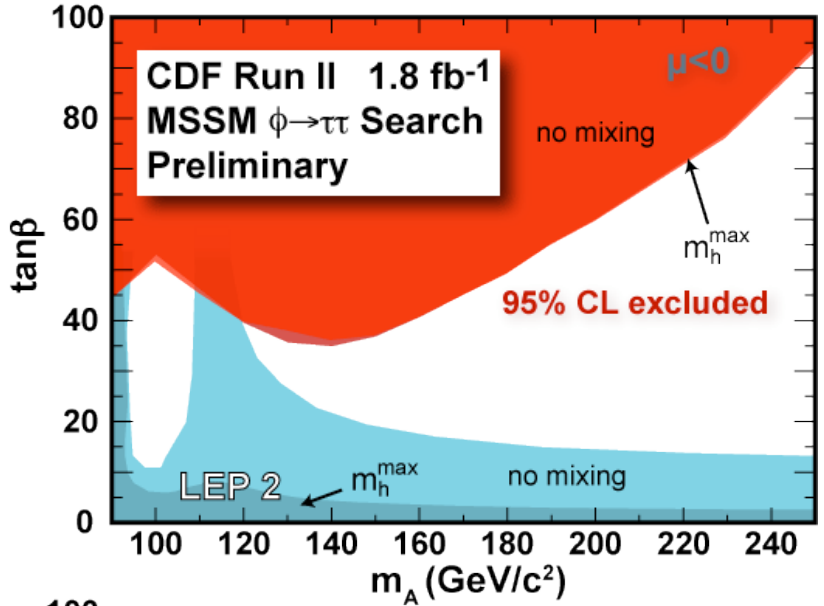
- Analysis performed with **2.0 fb^{-1}**
- Basic requirements: **3 b**-tagged jets
- Modeling of **QCD background** is not trivial

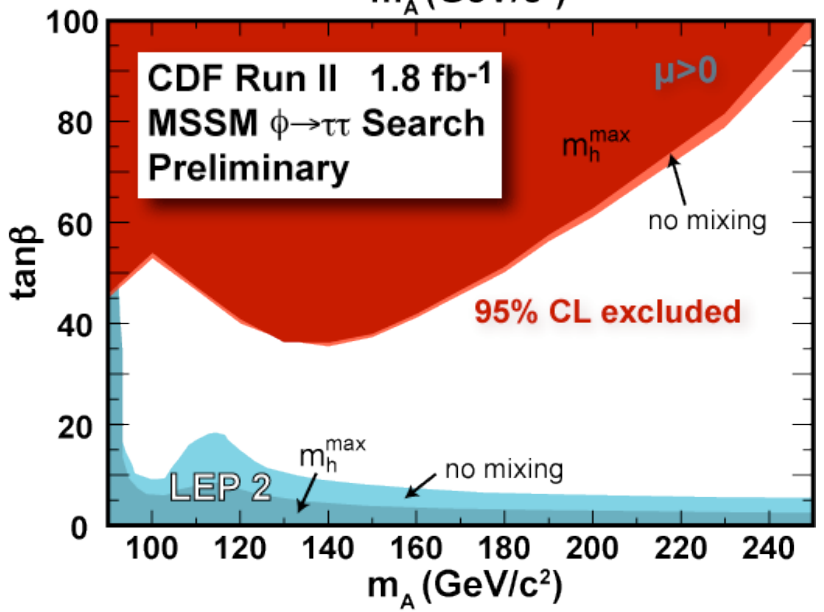


Neutral Higgs: H → τ τ



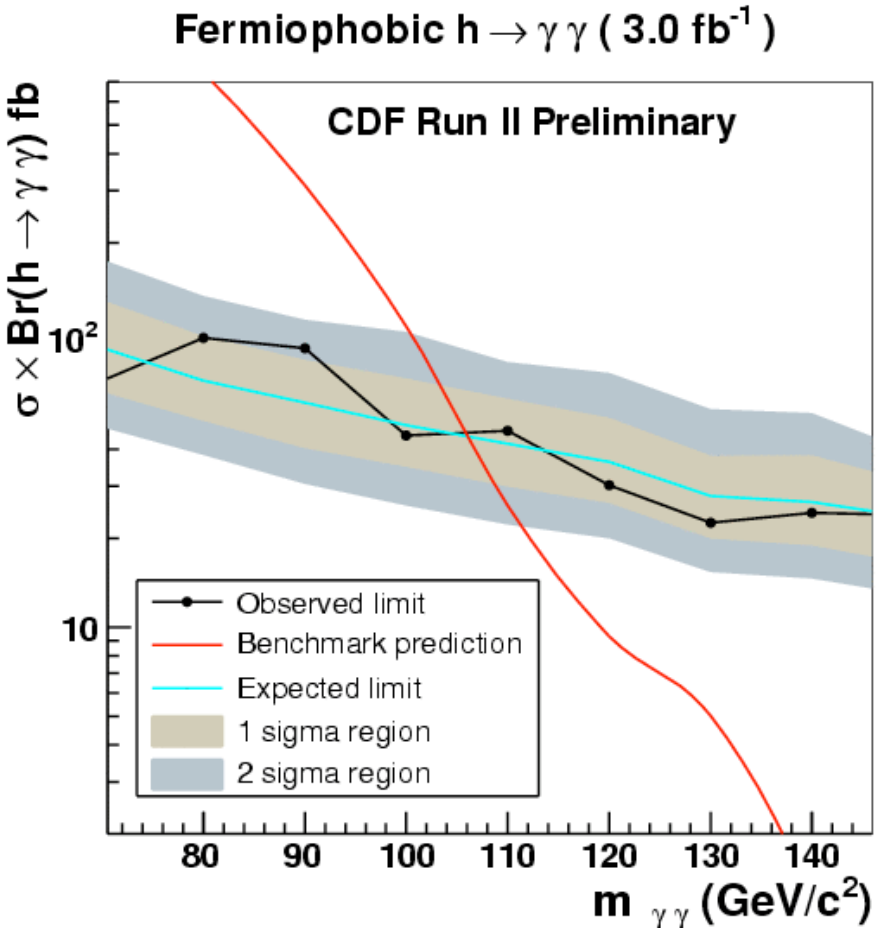
- Analysis performed with **1.8 fb^{-1}**
- Basic requirements: **2 tau leptons**, at least one leptonically decaying tau
  - **three different channels**
- Inclusive search: **both production** mechanisms probed
- **Profiled likelihood scan** in signal cross section, with m_{vis} templates
  - **m_{vis}**: sum of tau products four-mom and E^{T}_{miss})
  - all channels **fitted simultaneously**





Fermiophobic Higgs: H → γ γ

- Search for Higgs bosons that don't couple to fermions:
  - **BR to photons** is much larger than SM prediction
  - vector boson **associated production**
- Diphoton **resolution** < 3%
- Analysis performed with **3 fb^{-1}**
- Event requirements
  - at least 2 photons
  - at least 1 central photon
  - boosted diphoton system



Conclusions

- CDF has a **very active** program on SM and BSM **Higgs searches**
- Many channels, several techniques, continuos analysis upgrades keep providing **improving sensitivity**
- The Tevatron is **integrating luminosity** faster than ever
- **No evidence yet** of new particles, but the combined Tevatron sensitivity already reached Higgs SM predictions, **excluding a mass range** for the first time since LEP